

Biodiesel from Jatropha Oil as an Alternative Fuel for Diesel Engine

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Abstract— The world is getting modernized and industrialized day by day. As a result vehicles and engines are increasing. But energy sources used in these engines are limited and decreasing gradually. This situation leads to seek an alternative fuel for diesel engine. Biodiesel is an alternative fuel for diesel engine. The esters of vegetable oil animal fats are known as Biodiesel. This paper investigates the prospect of making of biodiesel from jatropha oil. Jatropha curcas is a renewable non-edible plant. Jatropha is a wildy growing hardy plant in arid and semi-arid regions of the country on degraded soils having low fertility and moisture. The seeds of Jatropha contain 50-60% oil. In this study the oil has been converted to biodiesel by the well-known transesterification process and used it to diesel engine for performance evaluation.

Index Term— Bio-diesel, Jatropha Oil and Trans-esterification Process.

I. INTRODUCTION

As civilization is growing, transport becomes essential part of life. The biggest problem is the growing population & depletion of fossil fuel. About 100 years ago, the major source of energy shifted from recent solar to fossil fuel (hydrocarbons). Technology has generally led to a greater use of hydrocarbon fuels, making civilization vulnerable to decrease in supply. This necessitates the search for alternative of oil as energy source.

Biodiesel is an alternative fuel for diesel engine. The esters of vegetable oils and animal fats are known collectively as biodiesel. It is a domestic, renewable fuel for diesel engine derived from natural oil like Jatropha oil. Biodiesel has an energy content of about 12% less than petroleum-based diesel fuel on a mass basis. It has a higher molecular weight, viscosity, density, and flash point than diesel fuel.

Jatropha curcas is unusual among tree crops is a renewable non-edible plant. From jatropha seeds jatropha oil can be extracted which have similar properties as diesel but some properties such as kinematic viscosity, solidifying point, flash point and ignition point is very high in jatropha oil. By some chemical reactions, Jatropha oil can be converted into biodiesel. Jatropha oil can also be used directly by blending

with diesel. Some benefits of jatropha oil are as follows:

- (i) The oil is being extensively used for making soap in some countries because it has a very high saponification value.

- (ii) The oil is used as illuminants as it burns without emitting smoke.
- (iii) The latex of jatropha curcas contains an alkaloid known as "jatrophine" which is believed to have anti cancerous properties.
- (iv) From the bark of jatropha curcas a dark blue dye is produced which is used for coloring cloth, fishing nets etc.
- (v) The byproduct of jatropha seeds contain high nitrogen, phosphorous and potassium which is used for fish foods, domestic animals food and in lands as fertilizer.

Now a day it has found that jatropha may display certain anti tumor and anti malarial properties and research is advancing related to HIV/ AIDS. Alternative fuels, other than being renewable, are also required to serve to decrease the net production of carbon dioxide (CO_2), oxides of nitrogen (NO_x), particulate matter etc. from combustion sources.

The production of biodiesel is limited by land area but jatropha curcas trees can be cultivated in any kinds of land. Jatropha is a wildy growing hardy plant, in arid and semi-arid regions of the country on degraded soils having low fertility and moisture. It can be cultivated successfully in the regions having scanty to heavy rainfall even it can be cultivated even on fallow and barren lands. There is huge unused area in southern part of Bangladesh, where jatropha can be cultivated with profitable income. The seeds of jatropha contain 50-60% oil. So Bangladesh can produce a huge amount of biodiesel from jatropha curcas and can save a large amount of importing of petroleum products from foreign countries.

The purpose of this research work is to investigate the fuel properties of Jatropha oil and production of bio-diesel from Jatropha oil. Investigate the fuel properties of bio-diesel and performance test diesel engine by using bio-diesel.

II. METHODOLOGY

The use of biodiesel is an effective way of substituting diesel fuel in the long run. One important conclusion that can be drawn from the work done earlier is that the vegetable oils can't be used directly in the diesel engine. Several problems crop up if unmodified fuel is used and viscosity is the major factor. It has been found that transesterification is the most effective way to reduce the viscosity of vegetable

oils and to make them fit for their use in the present diesel engines without any modification.

Transesterification is the process by which biodiesel is produced. In this process an ester reacts with an alcohol to form another ester and another alcohol. The catalyst for this reaction is KOH or NaOH. Three mol methanols react with one mol triglyceride which produces mixture of fatty esters and glycerin. The industrial-scale processes for transesterification of vegetable oils were initially developed in the early 1940s to improve the separation of glycerin during soap production.

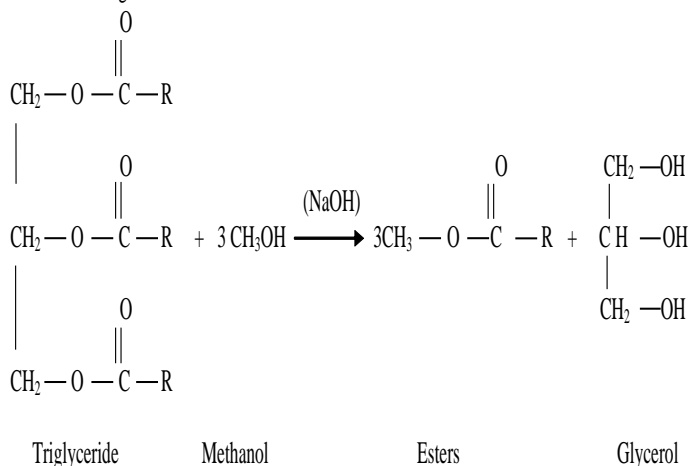
The primary input is assumed to be oil that has previously been extracted from jatropha oilseed. To accomplish the transesterification reaction described above, the oil, methanol, and catalyst are mixed together in a stirred reactor. 55 °-60 °C temperatures will cause the reaction to reach equilibrium more rapidly; in most cases the temperature is kept below the normal boiling point of the methanol (65°C) so the reactor does not need to be pressurized.

As shown in the reaction equation below, three moles of methanol react with one mole of triglyceride. In practice, most producers will use at least 100% excess methanol (6:1 molar ratio) to force the reaction equilibrium towards a complete conversion of the oil to biodiesel. The reaction is slowed by mass transfer limitations since at the start of the reaction the methanol is only slightly soluble in the oil and later on, the glycerin is not soluble in the methyl esters.

Since the catalyst tends to concentrate in the glycerin, it can become unavailable for the reaction without agitation. A common approach to overcome this issue is to conduct the transesterification in two stages. First, the oil is combined with 75% to 90% of the methanol and catalyst and this mixture is allowed to react to equilibrium. Then, the glycerin that has formed is separated by gravity separation and the remaining 10% to 25% of the methanol and catalyst is added for a second reaction period. At the conclusion of this second reaction period, the remaining glycerin is separated and the biodiesel is ready for further processing. The glycerin separation steps are usually accomplished by gravity settling or with a centrifuge

After the biodiesel is separated from the glycerol, it contains 3% to 6% methanol and usually some soap. If the soap level is low enough (300 to 500 ppm), the methanol can be removed by vaporization and this methanol will usually be dry enough to directly recycle back to the reaction. Methanol tends to act as a co-solvent for soap in the biodiesel, so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed.

The reaction is given below:



Where R is long hydrocarbon chains, sometimes called fatty acid chains.

After the methanol has been removed, the biodiesel needs to be washed to remove residual free glycerin, methanol, soaps, and catalyst. This is most frequently done using liquid-liquid extraction by mixing water with the biodiesel and gently agitating them to promote the transfer of the contaminants to the water without creating an emulsion that might be difficult to break. The washing process is usually done multiple times until the wash water no longer picks up soap. Although the gray water from later washes can be used as the supply water for the earlier wash steps, the total amount of water will typically be one to two times the volume flow rate of the biodiesel. Sometimes, to reduce the amount of water required, producers will add acid to the wash water. Weaker organic acids, such as citric acid, will neutralize the catalyst and produce a soluble salt.

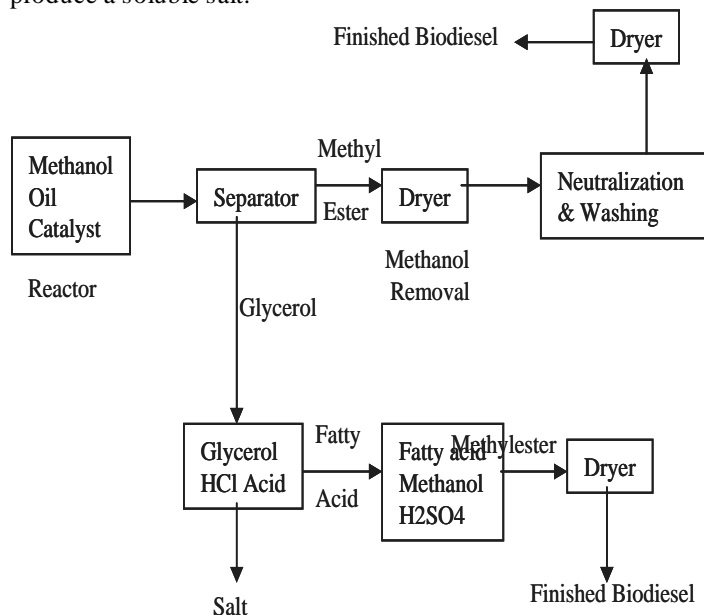
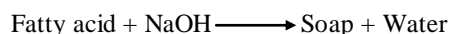


Fig. 1. Schematic of Biodiesel Processing.

Stronger inorganic acids, such as hydrochloric, sulfuric, or phosphoric, can be used to split the soap and this reduces the water requirement to 5% to 10% of the biodiesel flow because the salts are easier to remove than the soap. After washing, the biodiesel is frequently cloudy due to small water droplets suspended in the fuel. While these droplets will eventually settle out, it is much faster to use a flash evaporator to remove the residual water from the fuel.

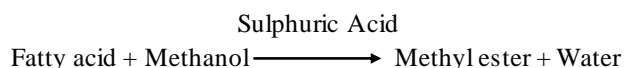
The glycerin that is separated from the biodiesel will contain a substantial amount of methanol, most of the catalyst, soaps that have been formed during the reaction and many of the polar contaminants that were originally present in the oil. These contaminants contribute to a dark brown or black color for the glycerin in spite of it being clear when present as a pure compound. The raw glycerin has very little value and must be upgraded to raise its purity before it can be sold. The usual practice is to add strong hydrochloric acid to the glycerin to neutralize the catalyst and split the soap.

The reactions are given below:



The soaps split into free fatty acids (FFAs) and salt, as shown in the equation. The FFAs are not soluble in the glycerin and can be separated with a centrifuge. The methanol can be removed by vaporization leaving a crude glycerol that is 80% to 90% pure. Most of the impurities will be salts. Only a few of the biodiesel producers in the U.S. have invested in the equipment to refine this crude glycerol to the 99.5% purity required for pharmaceutical and cosmetic applications. The fatty acids are not soluble in the glycerin and can be separated with a centrifuge. These high free fatty acid oils present special challenges when used for biodiesel production. When an alkali catalyst is added to these feed stocks, the free fatty acid reacts with the catalyst to form soap and water as shown in the above reaction. This reaction makes the catalyst unavailable for catalyzing the reaction and if enough soap is produced it can inhibit the separation of the methyl esters and glycerin.

When oils and fats with high free fatty acids are to be used for biodiesel production, an acid catalyst such as sulfuric acid can be used to esterify the free fatty acids to methyl esters as shown in the following reaction.



Then, the Methanol with the FFAs converted to

methyl esters, a conventional alkali-catalyzed process can be used to transesterify the triglycerides in the feedstock. While acids can be used to catalyze the transesterification reaction, the reaction is very slow at the 50° to 60°C reaction temperature the two-step approach of acid-catalyzed esterification followed by base-catalyzed transesterification gives a complete reaction at moderate temperatures. A problem with this approach is that the water produced by the esterification reaction should be removed before the base-catalyzed process begins so that soap formation is not excessive. This can be done by settling or centrifuging the methanol-water-acid layer that separates after the esterification has reached equilibrium. The additional equipment required for the acid-catalyzed pretreatment raises the processing cost, but this approach allows the use of feed stocks containing up to 100% FFA. Finally after drying the found methyl ester is converted to the required biodiesel. Hence, it is seen that 900ml biodiesel is produced from 1 liter of Jatropha oil.



Fig. 2. Seeds of Jatropha



Fig. 3. Jatropha oil



Fig. 4. During the Biodiesel production



Fig. 5. Biodiesel

III. EXPERIMENTAL SET-UP AND PROCEDURE

The final product of biodiesel from Jatropha oil is used as an alternative fuel to operate diesel engine in the Heat Engine Laboratory of Department of Mechanical Engineering, Khulna University of Engineering & Technology. The tested engine specification is shown in Table-A and photograph is shown in Fig. 5. The engine has been run using biodiesel and required data are collected to calculate the engine performance parameters.



Fig. 5. Photograph of Experimental Set-Up

TABLE-A
ENGINE SPECIFICATION

Model	06-TCVenaria
Type	Vertical, four cylinder, in line, air-cooled, diesel cycle
Bore or diameter(mm)	76.1
Stroke(mm)	71.5
Total swept volume(cc)	1301
Compression ratio	20
Maximum torque(DIN standards)	7.2 kg-m(71 Nm) at 2500 rpm
Method of cooling	Air cooling by fan
Method of lubrication	Centrifugal lubrication, combined oil mist and splash.
Method of starting	By using starting motor
Voltage of electric installation i.e. Battery(v)	12v, 21 plate
Ignition sequence	1-3-4-2
Distribution	Single-shaft in the cylinder head with toothed belt drive
Injection pump	BOSCH rotary pump
Oil sump capacity(l)	4
Clearance of cold tappets (mm)	0.40(intake), 0.50(exhaust)
Optimal utilization of engine speed (R pm)	1500-4000

IV. RESULTS AND DISCUSSION

TABLE I
THE OBSERVED PROPERTIES OF OIL AND FUELS

Properties	Jatropha Oil*	Biodiesel	50% Biodiesel & 50% Diesel	Diesel*
Density [gm/cc]	--	0.62	0.58	0.84
Kinematic viscosity at 30°C	55	5.34	6.86	4.0
Calorific value [MJ/kg]	39.5	41	42.7	45
Cetane number	43	--	--	47
Solidifying point °C	-10	--	--	-14
Boiling point °C	286	255	--	248

TABLE II

THE OBSERVED ENGINE PERFORMANCE USING DIESEL AND BIODIESEL

Performance	Diesel	Biodiesel	50% Biodiesel & 50% Diesel
Brake power, kw	0.466	0.895	0.339
Specific fuel consumption, g/kw-hr	784	629.74	1298
Mass of fuel, kg/hr	0.712	0.62	0.44
Brake thermal efficiency, %	11.76	24.09	10.8
Mass of air, kg/hr	7.94	5.52	8.49
Air fuel ratio	31.15	8.9	19.3

TABLE III

THE EXHAUST GAS ANALYSIS BY ORSAT APPARATUS

% of sample gas	Diesel	Biodiesel	50% Biodiesel & 50% Diesel
CO ₂	9	1.33	5
O ₂	5	17.67	8
CO	1	0	1

From the present research it is found that the calorific value of biodiesel is almost same as the diesel.

It has been found that the performance of biodiesel, mixture of 50% biodiesel & 50% diesel and compared with diesel and found that the brake power, brake thermal efficiency is greater than diesel and mass of air, fuel consumption, mass of fuel of biodiesel and air fuel ratio is less than diesel. It is also found that brake power, brake thermal efficiency, mass of fuel of biodiesel is greater than 50% biodiesel & 50% diesel and mass of air and air fuel ratio of biodiesel is less than mixture of 50% biodiesel & 50% diesel.

From the analysis of exhaust gas it is observed that % of CO₂ gas of biodiesel is very lower than the diesel and also from the mixture of 50% biodiesel & 50% diesel. The % of O₂ of biodiesel is very higher than the diesel and nearly with mixture of 50% biodiesel & 50% diesel. And the % of CO is zero for biodiesel & one for other two compositions.

As far as the utilization of the seed cake is concerned, niche formation processes are hardly present. The seedcake pressed into briquettes, which can be used as fuel in wood stoves or ovens. Using seedcake as fertilizer could be more promising because of its favorable nutritional qualities. Potential actors in this domain are farmers who want to use the cake as fertilizer, and the oil pressing facilities, which generate *Jatropha* cake as a by-product. It would appear to be highly important for this niche to develop, because *Jatropha* cultivation itself stands to benefit from it.

The by-products of Transesterification process; glycerin and soap can also be the source of income. By supplying the processed glycerin in the market money can be made. And small-scale *Jatropha* soap contributes on the economics.

Because, the soap, itself is a good product with strong antiseptic qualities. It commands a high price compared to ordinary soaps, so only a minority of people can afford it. The expectation is that this market will not expand much beyond its current size.

From the above discussion it is clear that biodiesel from *Jatropha* oil is very necessary to us. It reduces green house effect on our environment by reducing CO₂ gas emission. It is very friendly with environment because it increases percentage of O₂ in exhaust gas than the ordinary diesel. The economics of biodiesel fuels compared to traditional petroleum resources are marginal; public policy needs to be revised to encourage development. As *Jatropha curcas* is easy to cultivate so by planting of *Jatropha*, Bangladesh can save a huge amount of importing of petroleum products from foreign countries.

V. CONCLUSION

Biodiesel is a viable substitute for petroleum-based diesel fuel. Its advantages are improved lubricity, higher cetane number, cleaner emissions (except for NO_x), reduced global warming, and enhanced rural development. *Jatropha* oil has potential as an alternative energy source. However, this oil alone will not solve our dependence on foreign oil within any practical time frame. Use of this and other alternative energy sources could contribute to a more stable supply of energy. Major production centers on the level of modern petroleum refineries have not been developed. The economics of biodiesel fuels compared to traditional petroleum resources are marginal; public policy needs to be revised to encourage development. Increased *Jatropha* oil production would require a significant commitment of resources. Land for production would need to be contracted, crushing and biodiesel production plants need to be built, distribution and storage facilities constructed, and monitoring of users for detection of problems in large-scale use are all needed to encourage development of the industry. To meet the challenges of excessive import, we have to strengthen our oilseed sector and lay special emphasis on harnessing the existing and augmenting future potential source of green fuel. The organized plantation and systematic collection of *Jatropha* oil, being potential bio-diesel substitutes will reduce the import burden of crude petroleum substantially. The emphasis should be made to invest in agriculture sector for exploitation of existing potential by establishing model seed procurement centers, installing preprocessing and processing facilities, oil extraction unit, trans-esterification units etc. There is also need to augment the future potential by investing largely on compact organized plantation of *Jatropha* on the available wastelands of the country. This will enable our country to become independent in the fuel sector by promoting and adopting bio-fuel as an alternative to petroleum fuels. It is evidenced that there are new work opportunities in *Jatropha* cultivation and biodiesel production related sectors, and the industry can be grown in a manner that favors many prosperous independent farmers and farming communities.

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